SYSTEM AND METHOD FOR REVERSE LINK OVERLOAD CONTROL

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the field of wireless communications.

2. Description of Related Art

In contrast to Time Division Multiple Access (TDMA) and Frequency Division Multiple-access (FDMA) techniques, which create multiple communication channels from a single radio frequency (RF) bandwidth by assigning different time slots to mobile subscriber terminals ("mobiles") and subdividing an RF band into a plurality of sub-bands respectively, systems which are based on spread spectrum techniques, such as Code Division Multiple Access (CDMA) systems, exhibit "soft capacity" by using orthogonal code sequences to differentiate mobiles. In other words, the number of mobiles that a single cell/sector of a CDMA system can support at one time is not fixed, and instead is generally limited only by the degradation of service quality caused by interference from other mobiles in the same or adjacent cells/sectors.

To address this tradeoff between network capacity and service quality, CDMA system architectures typically utilize reverse link, i.e., mobile to base station, power control techniques by which the base station adaptively sets the transmit power of each mobile being served to the minimum level required to maintain adequate performance (usually assessed by comparing the ratio of energy per bit, E_b, to interference, N_o, at the base station with a target E_b/N_o value). As interference at a network base station increases with increased reverse link load levels (hereinafter "load levels"), the base station issues mobile transmit power up-adjust commands as needed. At high load levels, the substantial interference

which is likely to occur at the base station prompts the base station to issue an increased number of power up-adjust commands, particularly to those mobiles at outer cell/sector boundaries, thereby resulting in even greater interference at the base station. If not otherwise addressed, such increases in interference ultimately result in loss of base station coverage area (i.e., cell/sector shrinkage) because distant mobiles will not be able to transmit at the power level needed to achieve adequate call quality. Therefore, calls from such distant mobiles may be dropped under high load conditions.

To protect against such instability and loss of base station coverage area, CDMA networks commonly rely on call admission schemes, whereby mobiles in a heavily loaded cell/sector may be denied service from the corresponding base station. Assuming a static environment, the maximum number of users, N_{max}, that can be served in a CDMA cell/sector (i.e., a 100% load level) can be expressed as:

$$N_{\max} = \frac{PG}{v\frac{E_b}{N_o}} x \frac{1}{\beta}, \qquad (1)$$

where PG is the processing gain of the CDMA system and is defined as the ratio of bandwidth used to the data rate achieved, v is the voice activity, and β is the reuse efficiency of the CDMA cellular approach and is defined as the ratio of interference from other cells/sectors to interference within the cell/sector. When the cell/sector serves N users, the load level can be expressed as:

$$L = \frac{N}{N_{\max}} = \frac{Nv\frac{Eb}{No}}{PG} x\beta . \qquad (2)$$

Measured E_b/N_o, voice activity v, and CDMA reuse efficiency β are typically varying quantities, however. In particular, feasible approaches for accurately measuring β are unknown, and, thus, the above expression cannot be used in practice to determine load levels.

One current approach calculates load levels as a function of the ratio of total receive power rise measured at the base station to background noise. More specifically, as set forth in R. Padovani, *Reverse Link Performance of IS-95 Based Cellular Systems*, IEEE Personal Communications, pp. 28-34, 1994, there is a direct relationship between load levels and the ratio of total received power at the base station to background noise, which may be expressed as:

$$L = 1 - \frac{1}{Z}, \tag{3}$$

where Z is the ratio of total receiver power to background noise. Background noise includes thermal noise as well as other non-CDMA interference such as jammer signal power. A drawback of this approach, however, is the difficulty of obtaining an accurate measure of background noise, and in particular thermal noise, in a dynamic network environment, and therefore accurate reverse link load level calculations utilizing the above expression cannot typically be realized.

SUMMARY OF THE INVENTION

The present invention is a system and a method for controlling call admission in a wireless communications network which estimates load levels as a function of changes in base station receive power and/or changes in the number of mobiles served in the cell/sector (hereinafter "number of users"). In one embodiment, the present invention is a call admission controller of a wireless network base station, such as a CDMA base station, which utilizes multiple load level estimating methods, whereby a first load level estimating method generates an initial load level estimate, and at least one additional estimating method recursively generates updated load level estimates as a function of changes in the number of users and/or changes in base station receive power.

In one implementation, a call admission controller receives initial and updated number of users and base station receive power measurements, and estimates load level, L_{new}, as:

$$L_{new}(N_{new,}P_{new}) = \frac{N_{new}\, x\,(P_{new} - P_{old})}{N_{new}\, x\,(P_{new} - P_{old}) + P_{old}\; x\,(N_{new} - N_{old})}, \tag{4}$$

where N_{new} and N_{old} are integer values representing the current and previous number of users values respectively, and P_{new} and P_{old} are current and previous base station receive power measurements respectively.

Subsequently, the call admission controller recursively updates load level estimates as being linearly proportional to a change in the number of users by calculating:

$$L_{new} = L_{old}\; x\, \frac{N_{new}}{N_{old}}, \tag{5}$$

where L_{old} represents the previous load estimate. Recognizing that load level may not change in linear proportion to changes in the number of users under certain conditions, such as when significant changes in background noise or reverse link power from mobiles in nearby cells/sectors occur, the call admission controller verifies the load level previously estimated as a function of changes in the number of users by calculating an estimated base station receive power, $P_{new'}$, as a function of the estimated load level, in accordance with the expression:

$$P_{new'} = \frac{P_{old}(1 - L_{old})}{(1 - L_{new})}, \tag{6}$$

and compares $P_{new'}$ with an actual base station receive power level. When $P_{new'}$ is not sufficiently close to measured base station receive power, the call admission controller uses a third load level estimating method, which recursively estimates load level as a function of changes in base station receive power, by calculating:

$$L_{new} = 1 - \frac{P_{old}}{P_{new}} x (1 - L_{old}) \quad (7).$$

By estimating load levels as a function of changes in the number of users and/or base station receive power measurements, load estimation according to the present invention is not dependent on determining background noise. Furthermore, by recursively updating load level estimates using multiple techniques, estimate inaccuracies can be avoided.

BRIEF DESCRIPTION OF THE DRAWINGS

Other aspects and advantages of the present invention will become apparent upon reading the following detailed description, and upon reference to the drawings in which:

Fig. 1 illustrates select components of an exemplary call admission controller according to embodiments of the present invention; and

Fig. 2 is a flow diagram illustrating a load level estimating operation employed by the call admission controller according to embodiments of the present invention.

DETAILED DESCRIPTION

The present invention is a system and method for controlling call admission in a wireless communications network which estimates load levels as a function of changes in base station receive power and/or the number of users. In one embodiment, the present invention is a call admission controller of a wireless network base station, such as a CDMA base station, which utilizes a first load level estimating method to generate an initial load level estimate, and at least one additional load level estimating method to recursively update load level estimates as a function of changes in the number of users and/or base station receive power measurements. An illustrative embodiment of a system and method

for controlling call admission in a wireless communications network according to the present invention is described below.

Referring to Fig. 1, there is shown a call admission controller 100 which includes a load estimator 110, a memory unit 115, and a comparator 120. The load estimator 110 receives base station receive power values, e.g., from the base station power measurement circuitry (not shown), and also number of users values, e.g., from the base station call processing unit (not shown). The call admission controller 100 may be implemented as a routine of the base station call processing unit software, which denies a mobile's request to communicate with the base station under high load conditions. As discussed below, the load estimator 110 utilizes base station receive power measurements and number of user values to estimate load levels, and outputs the result to a first input of the comparator 120. As is well known in the art, base station receive power measurements may be represented by Received Signal Strength Index (RSSI) values which are typically collected at the network base station. The memory unit 115 stores a load level threshold, e.g., 0.7, which is received at the second input of the comparator 120. When the comparator 120 determines that the load level estimate received from the load estimator 110 exceeds the load level threshold received from the memory unit 115, the comparator 120 outputs a call blocking command signal which commands the base station call processing unit to block additional mobile requests to communicate with the base station. By outputting call blocking commands when load levels exceed a threshold, the call admission controller 100 prevents cell/sector overload conditions which may lead to the network instability and loss of cell/sector coverage area discussed above.

The operation of the load estimator 110 for estimating initial and updated load levels will next be described with reference to the flow diagram of Fig. 2. It should be realized the load estimator 110 may be

realized as a computer implemented algorithm, or as programmable or dedicated logic circuitry, for performing the operations detailed below.

Initially, the load estimator 110 sets a counter index, *counter*, and a time index, *time*, to 0 (Step 202). Next, the load estimator 110 sets an initial base station receive power value, P_{old}, to a recently received base station received power measurement. In practice, P_{old} may be set to a statistical average of multiple base station receive power measurement values taken over a sampling period, e.g., the mean of 100 RSSI samples, thereby enhancing accuracy. The base station receive power measurements are preferably in dBms, but also may be represented in Watts. In addition to setting an initial value for P_{old}, the load estimator 110 sets a number of users value, N_{old}, to a number of users value received from the base station's call processing unit (Step 204).

Next, the load estimator 110 increments *time* by 1 (Step 206), and obtains a new base station receive power measurement and number of users value, which are used to set P_{new} and N_{new} respectively (Step 208). It may be assumed that load level is low relative to the load level threshold when few mobiles are being served, and, thus, the load estimator does not attempt to estimate load until N_{new} exceeds a certain level, N_{init}. The load estimator 110, thus, compares N_{new} and N_{init} (Step 210), and returns to Step 206, i.e., increments *time* by 1, when N_{new} is not at least equal to N_{init}, and increments *counter* by 1 when N_{new} is at least equal to N_{init} (Step 212). After determining that N_{new} exceeds N_{init} at Step 210, and incrementing *counter* at Step 212, the load estimator 110 determines whether *counter* = 1 (Step 214).

When *counter* = 1, the load estimator 110 compares $|N_{new} - N_{old}|$ and a threshold value, N_{th} (Step 216). When $|N_{new} - N_{old}|$ is not at least equal to N_{th}, the load estimator 110 resets *counter* to 0 (step 218), and returns to Step 206. When, on the other hand, $|N_{new} - N_{old}|$ is at least equal to N_{th}, the load estimator 110 estimates a load level, L_{new}, in

accordance with a first estimating method (Step 220). By not calculating a load level estimate until $|N_{new} - N_{old}|$ at least equals N_{th}, e.g., $N_{th} = 3$, more stable and accurate calculations are achieved.

According to one specific implementation of the present invention, the first estimating method determines L_{new} as a function of changes in base station receive power measurements and changes in number of users values. Specifically, the load estimator 110 calculates:

$$L_{new}(N_{new}, P_{new}) = \frac{N_{new}\, x\,(P_{new} - P_{old})}{N_{new}\, x\,(P_{new} - P_{old}) + P_{old}\, x\,(N_{new} - N_{old})} \quad (4).$$

After an initial estimate of L_{new}, to enable subsequent recursive load level estimates, L_{old} is set to equal L_{new}, P_{old} is set to equal P_{new}, and N_{old} is set to equal N_{new} (Step 222). Next, the load estimator 110 determines whether a reset condition has occurred (Step 224), e.g., when a call processing software update is required, or as otherwise needed. When reset occurs, the load estimator 110 returns to the initialization Step 202. When no reset condition has occurred, the load estimator 110 returns to Step 206 to increment *time* by 1.

When *counter* $\neq 1$ at Step 214, the load estimator 110 estimates load level using a second estimating method (Step 226). The second load estimating method recognizes that changes in load level are typically linearly proportional to a changes in number of users values. Specifically, the second load level estimating method is expressed as:

$$L_{new} = L_{old}\, x\, \frac{N_{new}}{N_{old}} \quad (5).$$

change?

To confirm that the second load level estimating method yields a reasonably accurate result, the load estimator 110 calculates an estimate of P_{new}, $P_{new'}$, using the L_{new} value obtained from the second load level estimating method (Step 228). Specifically, the load estimator 110 calculates:

$$P_{new'} = \frac{P_{old}(1-L_{old})}{(1-L_{new})} \quad (6).$$

Next, the load estimator 110 compares $P_{new'}$ with an actual base station receive power measurement (Step 230). When $P_{new'}$ is reasonably close to the actual base station receive power measurement (e.g., +/- 5%), the load estimator 110 outputs the result of the second load level estimating method to the comparator 120, and returns to Step 222. When $P_{new'}$ is not sufficiently close to the measured power value, the load estimator 110 utilizes a third load level estimating method to obtain L_{new} (Step 232). The third load level estimating determines that load levels change as a function of a change is base station receive power measurements. ✓ Specifically, the load estimator 110 calculates:

$$L_{new} = 1 - \frac{P_{old}}{P_{new}} x\,(1-L_{old}) \qquad 1-\frac{P_{old}}{P_{new}} \quad (7).$$

The load estimator 110 outputs the result from the third load level estimating method to the comparator 120, and returns to Step 222 so that the load level may be recursively updated (e.g., updated every 2 seconds).

By using a plurality of recursive load level estimating methods, such as those described above, inaccuracies may be avoided. Furthermore, by recognizing differential relationships between load levels, base station receive power measurements, and the number of users, load levels are accurately estimated without relying on background noise measurements.

It should be apparent to those skilled in the art that various modifications and applications of this invention are contemplated which may be realized without departing from the spirit and scope of the present invention.